Neural network for classification of asteroid spectra

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Introduction

Asteroid mineral composition is important parameter in planetary science, planetary defence, and in-space resource utilisation. Currently-used methods provide us mainly quantitative information about the asteroid composition. The methods are based on empirical relations between spectral parameters (band areas, positions, depths), or on spectral unmixing, and are highly sensitive to quality and consistency of input reflectance spectra. We test artificial neural networks as a tool which can infer mineral composition directly from the reflectance values.

Methods

Artificial neural networks are used in tasks which are very difficult to define with exact mathematics. A sensitivity of the networks to quality of input data (e.g., absolute reflectance values or variations in spectral slope) can be partially suppressed. The networks are made of layers of neurons. Each neuron in a layer is non-linearly connected with neurons in the previous and following layers. The non-linearity and complexity of neural network enable them to solve various tasks.

We use neural network for computing of mineral composition of the most common silicates presented in meteorites (olivine, orthopyroxene, clinopyroxene, and plagioclase). Our neural network composed of the input layer with reflectance values, one 'intermediate' layer (hidden layer), and the output layer. The outputs are modal composition of the minerals and their chemical composition represented with end-members.

Data

We utilised measured reflectance spectra from the Relab database[1]. We are motivated by the ASPECT instrument (part of Hera/Milany CubSat) which will carry-out observations in visible and near-infrared part of spectra. For this reason, we chose spectra which cover interval between 350 nm and 2550 nm with the resolution 15 nm or better.

Results

Olivine and orthopyroxene are the most common minerals in ordinary chondrites. Therefore, we firstly applied the neural network on a set of olivine and pyroxene spectra.

[1]http://www.planetary.brown.edu/relabdata/

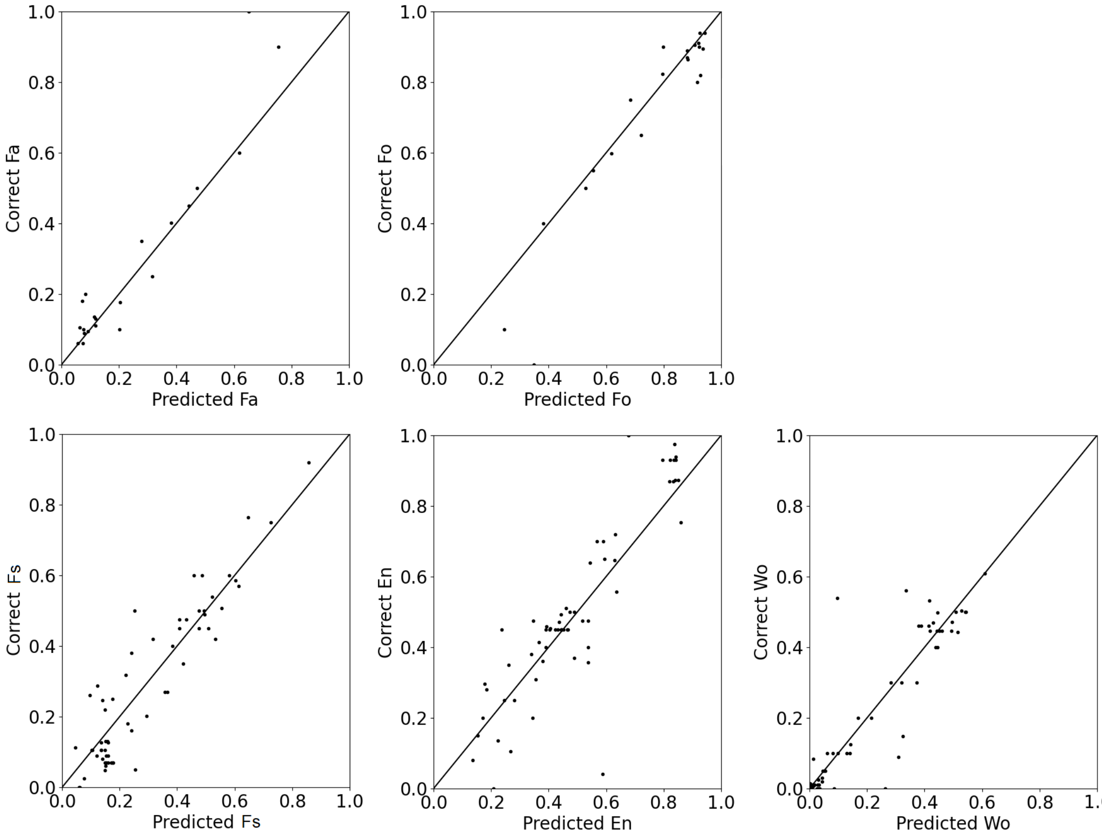

Figure 1: Results of chemical composition. Top row: olivine. Bottom row: pyroxene.

The neural network contained only one hidden layer with 30 neurons. The outputs were volume fractions of the minerals and their chemical composition. We trained the network on about 80% of the whole dataset and used the remaining 20% to test the accuracy of the predictions. The results obtained from the 20% are shown in Fig. 1. The vertical axes show the correct (previously published) values while the horizontal axes the values predicted by the neural network. In the top row, there are iron and magnesium composition in olivine. In the bottom row, there are iron, magnesium, and calcium composition in pyroxene.

Discussion

Except a few outlier, the predicted composition is usually within about 10% from the actual composition. The outliers might be a consequence of a limited training dataset or ambiguously determined actual composition. In the near future, the predictive capability of the network will be improved via optimisation of its architecture and due to increase number of training samples. In the next step, we will train the network on synthetic spectra of olivine, orthopyroxene, and plagioclase and evaluate the network on real ordinary chondrites.